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THE EFFECT UPON THE WHITE RAT OF CONTINUED BODILY ROTATION

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Everyone knows that a rapid turning-about upon the heels usually leads to dizziness and that a like state is induced in the revolving chair or the turn-table of the laboratory or in the merry-go-round of street fairs. It is also known, especially among those who have attempted to analyze the complicated experience of dizziness, that an important constituent of this disturbed state of mind and body is a characteristic movement, to-and-fro, of the eyes. To this ocular twitching, which is sometimes called "nystagmus," is due, in large measure, the apparent swimming movement of surrounding objects. The twitching appears soon after rotation begins and it continues, with characteristic modifications, for a short period after the body comes to rest.

The bodily and mental effects of rotation in man and in other animals have for a good many years been made the subject of investigation by physicists, anatomists, physiologists, psychologists and medical men. It is supposed that rotation produces a specific effect upon the neural end-organs of the semicircular canals, and it is definitely known that, in addition, pretty much the entire organism is involved in the general disturbance. Concerning the ocular movements themselves, a good deal has been learned. We know, for example, that the character and the duration of the nystagmus depend upon a large and heterogeneous group of conditions, among which may be named the general state of the organism, the state of attention, the associative connections, the rate, regularity and duration of the rotational movements, repetition and practise, and other mental and physical conditions. Of these conditions, we are here concerned with one only, *i. e.,* with the effect of regular and continued repetition upon the ocular movements in question.

It has been commonly observed that long persistence in whirling movements may reduce in intensity the distressing symptoms of dizziness. This reduction under repetition has suggested that the accompanying ocular movements may also tend, under persistent practise, to disappear. The testimony of whirling dancers and gymnasts, who are frequently undisturbed by the swimming and the giddiness, points in this direction,[1] and further evidence, of an experimental sort,[2] has recently been derived from subjects who were rotated about three minutes daily for two or three weeks. At the end of this period the subjects had lost, either wholly or in part, the "after-nystagmus" which usually persists, as we have seen, when the body has come to rest.

Now these experimental results have been sharply criticized by two otologists, Drs. Fisher and Babcock,[3] who are distressed that the stability of such a "reflex reaction" as nystagmus should be called in question. "Clinical medicine has," as they observe, "for years relied upon the permanency and the constancy of reflex phenomena." As for the results just referred to, they set them down as "pathological." Professing to repeat the experiments, but wholly missing the essential point of the method which they criticize, these men have come, not unnaturally, to a conclusion which is not antagonistic to the dogma of the invariable reflex. Despite the miscarriage of their method, however, they do find a certain amount of reduction in time of nystagmus and this reduction they propose to explain by the voluntary "gaze-fixing" of "a few subjects." Although the abortive attempt of Fisher and Babcock affords no positive evidence against the demonstrated reduction of nystagmus under repetition,[4] it has suggested an *experimentum crucis* which is designed to show that the reduction is *not* an artefact produced by the "wilful gaze-fixing" of inconvenient subjects who acquired "the art of holding the eye more or less fixed voluntarily" upon a "distant object."

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[1] Parsons, R. P., and Segar, L. H., "A Correlation Study of Bárány Chair Tests and Flying Ability of One Hundred Navy Aviators," *J. Amer. Med. Ass.,* 1918, 70, 1064.

[2] *Manual of Medical Research Laboratory,* Washington, D. C., 1918, 186 ff.

[3] Fisher, L., and Babcock, H. L., "The Reliability of the Nystagmus Test," *J. Amer. Med. Ass.,* 1919, 72, 779 ff.

We have chosen the white rat as a subject in our crucial experiment. The rat is admirably adapted to this sort of problem. It is docile and easy to handle. The lack of a fovea and of distant vision and the probable absence of all clear-cut retinal images[5] seem to provide the optimal conditions of non-fixation as suggested by the otologists' contentions. On the other hand, the pupil of the rat's eye is easily observed, as well as those portions of the sclerotic coat which project beyond the surrounding cutaneous and hairy tissues.

The following method of rotation and observation was employed. Upon a pivoted wooden platform, 11 cm. × 20 cm., was set a glass bell-jar 11 cm. in diameter and 12 cm. in height. The rat was so placed under the glass jar that its center of gravity lay over the center of rotation. A small motor, governed by means of a friction-brake, served to provide a very regular and easily controlled means of rotating the platform and the jar. Records of the time of after-nystagmus were at first made with a stop-watch, but later with a key connected to an electric signal-marker which registered on a revolving smoked drum.[6] It was found, by preliminary trials, that the appearance of the nystagmus was directly proportional to the *number* of rotations and to the *speed* of rotation. For experimental purposes, an arbitrary choice was made of a speed of ten revolutions in fifteen seconds. Ten trials of ten rotations each were repeated two or three times a day, save for subjects "I" and "J," which were given twenty trials twice a day. The subjects were ten white rats, five males and five females, all about three months old. The functional integrity of the mechanisms of equilibrium[7] was roughly determined by observing the rats' behavior under daily conditions of life, and by throwing them into the air and dropping them. All of the subjects responded quickly and positively to such tests. In the subsequent experiments each rat was rotated a like number of times to the right and to the left, and averages of the duration (in seconds) of the nystagmus after stopping were computed. A comparison of these averages from day to day may be made from Table I.

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[4] As a matter of fact, these authors unwittingly furnish the most delicate and unimpeachable evidence *for* the very reduction which they deny. Although they apparently omitted to repeat at each sitting, giving each of the ten subjects included in their Table II only one turning to the right and one to the left, *in every single case the average nystagmus-time is less for the second five days than for the first five days.* That is to say that a *single turning* each day (not a series) is sufficient to reduce the time for subsequent days. The tendency to reduction must, then, be much greater than the first experimenters had contended or supposed.

[5] Vincent, S. B., "The Mammalian Eye," *J. of Animal Behavior,* 1912, 2, 249–255. See table and also references to the literature.

The outstanding feature of the investigation is the rapid decrease of after-nystagmus from day to day, as is clearly indicated in Table I. Within ten to eighteen periods of rotation the nystagmus had completely disappeared. The number of ocular movements after stopping the platform was also observed. Upon the first rotation for each rat, the number of movements varied between 18 and 25. This number rapidly decreased during the first four or five periods to between 5 and 8, and soon became reduced to a single movement which generally hung on for some time. As the rotation was stopped, the eye gradually moved in the direction of the preceding rotation and then jerked back to normal position. The

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[6] This latter method was used by the Psychological Department of the Mineola Research Laboratory. It is a decided improvement over the clinical method of observation by the stop watch. See "Manual," p. 190.

[7] The semicircular canals of Rodentia are well developed and quite regular in form. See Gray, A. A., "The Labyrinth of Animals," 1907, Vol. I, pp. 165 ff.

TABLE I

Subject......		A		B		C		D		E		F		G		H		I		J	
Direction of Rotation		L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R
Number of series	1	6.70	7.04	5.88	6.06	5.00	5.80	5.80	6.40	5.34	5.06	6.02	4.82	4.40	4.60	5.80	4.60	5.66	5.86	5.12	6.16
	2	5.62	5.80	4.52	4.90	4.96	4.60	5.32	5.20	4.76	4.02	4.20	5.12	4.60	4.60	6.00	5.00	4.35	4.45	3.96	4.06
	3	4.32	4.32	4.02	4.18	4.08	4.44	4.60	4.72	4.22	3.20	3.56	3.66	3.80	3.64	4.46	5.30	4.10	3.95	3.82	3.58
	4	3.78	4.10	3.70	3.76	3.26	3.92	4.08	4.20	2.58	1.80	3.56	2.64	4.78	4.30	3.88	4.04	3.00	2.98	3.72	3.30
	5	3.22	3.48	3.48	3.42	2.96	2.30	2.96	3.00	2.88	2.56	3.06	2.42	5.46	5.20	3.92	4.54	2,10	2.20	3.52	3.96
	6	2.68	2.62	2.70	2.58	1.28	1.28	1.78	1.96	1.50	1.36	1.28	1.50	4.46	4.34	4.20	4.64	1.18	1.56	2.74	2.94
	7	2.06	2.18	2.34	2.26	1.00	1.00	1.08	1.06	1.32	1.08	1.02	1.04	4.46	4.76	3.68	5.16	0.96	1.18	2.86	3.42
	8	1.62	1.74	1.74	1.80	0.60	0.60	1.00	1.00	0.60	0.86	1.00	1.00	4.18	3.68	3.58	3.18	0.40	0.50	2.96	2.92
	9	1.32	1.48	1.54	1.56	0.20	0.20	0.40	0.40	0.20	0.20	0.40	0.40	4.18	3.96	4.58	4.14	0.50	0,20	2.60	2.70
	10	1.04	1.56	1.26	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20	3.54	3.34	3.82	3.86	0.00	0.00	2.14	2.56
	11	1.00	1.00	1.22	1.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.72	3.58	2.96	3.42	0.00	0.00	1.60	1.58
	12	0.80	0.60	0.60	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0 00	3.66	3.76	3.10	3.40	0.00	0.00	1.76	1.38
	13	0.40	0.40	0.00	0.00									3.80	3.56	3.76	3.64			0.20	0.80
	14	0.00	0.00	0.00	0.00									3.50	3.74	3.68	3.60			0.10	0.20
	15	0.00	0.00	0.00	0.00									3.32	3.08	2.54	3.14			0.00	0.00
	16													2.24	1.84	2.16	2.18			0.00	0.00
	17													1.34	1.44	1.40	1.70				
	18													0.00	0.00	0.00	0.00				
	19													0.00	0.00	0.00	0.00				

disappearance of this one movement accounts for the sudden falling off of the time-values at the end of the various series. The average initial time of after-nystagmus for all subjects was 5.57 sec. for rotation to the left and 5.74 sec. for rotation to the right. Other averages testify to this difference in time for the two directions of rotation. This seems to be a genuine case of individual difference quite comparable to similar differences found in human observers.[8]

The fact of decrease from day to day is incontestable. Each column in Table I shows it. It is just as apparent, if, in each day's series, an average of the first two trials is taken and compared with corresponding values for subsequent days. That is, each day begins at just a little lower nystagmus-time than the preceding day began. Furthermore, the decrease is of a characteristic kind. Table I indicates that at least one half of the total decrease commonly occurs in the first few days of experimentation. The exceptions, subjects "G" and "H," will be considered later. In this respect, a "nystagmus curve" is quite comparable with the common "learning curve," save for the absence of plateaus.

Again, the figures make it plain that there is also a general decrease in the time of after-nystagmus within any single day's turning. Table II indicates that this decrease was constant for all subjects, save "G" and "H." An analysis of the material upon which the table is based shows that the main decrease within any single day falls early in the series—a result consonant with the early fall in time from day to day, as just mentioned.

It must be emphasized that any decrease is for one set of conditions only. Only those values are given which resulted when the rat rested quietly on the floor of the rotated platform. Occasionally the rat would stand almost upright, in which case the nystagmus was almost invariably longer. Even after the disappearance of the

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[8] See "Manual," *passim,* and also articles in the *J. Amer. Med. Ass.,* cited above.

TABLE II

Subject	L		R	
	I	II	III	IV
A	2.81	2.49	2.84	2.51
B	2.84	2.30	2.81	2.51
C	2.74	2.31	2.74	2.66
D	3.18	2.89	3.13	3.00
E	2.59	2.48	2.50	2.02
F	2.57	2.23	2.56	2.03
G	3.46	3.50	3.40	3.30
H	3.26	3.41	3.44	3.55
I	2.98	2.18	2.93	2.23
J	2.98	2.33	3.28	2.65

Column I, averages of all the first two rotations to the left for all series; column II, the average of all the last two rotations to the left for all series; columns III and IV, the same for rotation to the right.[9]

nystagmus under *usual* conditions, this upright posture induced some after-nystagmus; but it is important to note that the time and the intensity of it were never so great (by more than half) as the original nystagmus in these positions. That is, there seems to be a "transfer" effect from one set of conditions to another. Changing the speed or the number of rotations at any time produced a similar reappearance of nystagmus, but never in its original intensity or temporal duration. Several of the subjects gave a nystagmus varying between twelve and twenty-five seconds when rotated once a second for thirty seconds before the practise series. After the practise series, these values were reduced to about the level of the original values for the rotation-rate used in the investigation, viz., 5–6 seconds. The change of position of the rat during and after rotation had to be carefully regarded; for such a change was frequently responsible for an increase of nystagmus-time that obscured a real decrease.

There are several special points of importance.

1. It has been noted above that subjects "G" and "H" offer certain exceptions to our conclusions. Table I indi-

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[9] Mean variations from the averages given in the tables were computed; but since they were not of sufficient magnitude to affect the significance of the figures as given they have been omitted.

cates that the length of their total series was greater than that of any of the other rats. These two subjects were females rotated during the period of gestation. Their rotation was marked by frequent and severe retching movements, defecation, and micturition. The period of gestation of subject "G" was three days short. "G" became too sick during the last reported turning to be used further, and a day later, during which time she did not seem to recover, a litter of two were born. These coincidences point directly to the fact that nystagmus is closely related to the organic condition of the individual rotated and they at least suggest the fruitfulness of further work upon this matter.

2. The fact that the white rat is a nocturnal animal[10] suggested that the time of day might make a difference in values. Accordingly two rats, "I" and "J," were rotated twenty times twice a day, early in the morning and late in the afternoon. The results were as follows:

	I	J
Morning trials, rotation to left (ave.)	2.24	2.81
rotation to right (ave.)	2.37	3.17
Evening trials, rotation to left (ave.)	1.70	2.44
rotation to right (ave.)	1.88	2.40

The morning nystagmus is invariably longer, the difference being most pronounced early in the series. Additional evidence of this diurnal difference is being sought with both human and animal subjects.

3. Other responses than the nystagmus were scrupulously noted in our observations. During the first days, most of the subjects showed a tendency to excessive defecation and micturition. Frequently the feces were not of the solid character of normal life but were quite liquid, suggesting that the rotation had induced some sort of temporary organic shock. This supposition is supported by the facts that neither micturition nor defecation ever occurred late in the series and that the rats, although

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[10] Slonaker, J. R., "The Normal Activity of the Albino Rat, etc.," *J. of Animal Behav.*, 1912, 2, 20–42.

hungry, frequently refused to eat immediately after earlier turnings, although later they eat quite readily. Other evidence of a general organic disturbance is found in the violent trembling which frequently seized some of the rats during a given series. This trembling was distinct from that behavior mentioned before which reminds one of nothing so much as the retching of nausea in human beings. I have failed to find a single case of nauseation in the rat which resulted in an esophageal discharge. The retching did not seem to occur so readily if the rat had had food before the rotational period. The trembling was by far the most characteristic performance and was common to most of the subjects. That the trembling was organically based could be determined by holding the rat just after turning. The visceral organs seemed to be convulsed. The eyes were partially closed and the vibrissæ trembled violently because of the trembling of the mouth parts. This behavior occurred for two or three days after the series had been started and in the case of some of the subjects was the last observable response to the rotation.

4. It is difficult to get a quantitative test for these or for more specifically kinesthetic responses. The only test used in this connection was an enumeration of the number of spontaneous movements made before, during, and after rotation, as the series progressed. Prior to all rotation, the exploratory movements are prominent. As rotation takes place for the first time two kinds of response are in evidence. First, the rat may make frantic efforts to move in the direction contrary to rotation so long as the platform moves. When the movement ceases the rat turns and attempts just as vigorously to move in the opposite direction. These attempts always cease in five or six seconds: they seem to reach their term with the after-nystagmus. The other characteristic response is illustrated by those subjects which squat tensely on the floor of the rotating platform with the head turned far in the direction against rotation. There seems to be a specific

inhibition of all movement and a tenseness of position leading to what one might call the ''rotational posture.'' There is no change in the position until the end of the after-nystagmus, save that the head swings to the opposite side as rotation ceases. This second type of response can be easily induced in subjects manifesting the first kind by slightly increasing the speed of rotation. As the series proceeds, the more striking features of the rotational posture begin to drop out. The head tends to swing less and less in the direction opposite to rotation and very early the return movements—even the bringing of the head back to a straight position—disappear. Finally, the original swing itself becomes quite listless and may not occur at all provided the attention of the rat is elsewhere directed. The exploratory movements return slowly, beginning with the post-rotary period and finally entering the rotary period itself.

5. The scratch-reflex affords an excellent indication of the extensity and intensity of the bodily disturbance present during, and subsequent to, rotation. Early in a series, a scratch movement initiated before rotation is suddenly arrested as rotation begins. I have not observed any scratching during the earlier trials of a series. Subject ''J'' endeavored to scratch on the fourth day's rotation; but the effort was poorly localized and uncoordinated. At the end of the series, an accurately localized scratch-movement was begun and carried to completion by several subjects, and successful attempts were frequently made to cleanse the face, etc., in spite of rotation or stopping. As the exploratory movements came back to their own, the rat frequently stretched up on its hind legs. In such a position, the stopping of rotation caused a definite compensatory reaction on the part of the rat; but there was nothing here to indicate that this was more than a natural response to the effect of inertia. All of the spasmodic and uncoordinated qualities of an early event of this kind were gone. The tendency of some of the subjects to run in the direction opposite to rotation com-

pletely disappeared after a few trials. In brief, the whole series of any one of the subjects here reported displayed an increasing degree of freedom and precision of movement, as time went on. All subjects were tested for equilibration after a series had been completed and all responded to being thrown and dropped just as alertly as before rotation.

It is hazardous to draw general conclusions from an introductory study of this kind. Our problem does, however, bear directly and significantly upon the functional integrity of the equilibratory mechanisms. The facts above presented support the contention that nystagmus is closely related to the other organic responses to rotation and that it is dependent, as are these other responses, upon a large group of factors. Furthermore, we have found that after-nystagmus in the white rat decreases in intensity and duration (*a*) from day to day and (*b*) within the series of a single day. Either intensity or duration may be modified also by certain organic conditions, e. g., nausea, by speed and number of rotations, and by such general conditions as antecedent rest and fatigue. The decrease and disappearance of nystagmus are accompanied by a disappearance of the characteristic rotational posture and of other bodily disturbances, the disappearance being signalized by the reappearance of the usual exploratory movements and by such specific events as the scratch-reflex.

Fisher and Babcock tried to explain away the demonstrated loss of after-nystagmus under repetition (*a*) by charging that the human subjects were "pathological" and (*b*) by referring the observed decrease to a vicious practise acquired by "a few subjects" of "gaze-fixing" upon a "distant object." It is not clear just how their explanation can be extended to the white rats.